6.0 Example Calculations

With IWAIR, you can calculate estimates of cancer and noncancer inhalation risk or estimates of allowable waste concentration from a specified target risk level. The following example calculations demonstrate how IWAIR calculates risk or allowable concentration from emission rates and dispersion factors, using the equations presented in Section 6 of the *IWAIR Technical Background Document,* "Calculation of Risk/Hazard Quotient or Allowable Waste Concentration." You may either use IWAIR-calculated emission rates and dispersion factors or enter your own values; these example calculations do not cover how IWAIR calculates emission rates and dispersion factors.

The example calculations are based on a hypothetical exposure situation with the following conditions:

- The WMU modeled is a landfill.
- The waste managed in the landfill contains the carcinogen hexachlorobenzene and the noncarcinogen acrolein.
- The emission rates and dispersion factors are IWAIR-calculated values, not user-override values.
- The exposed individual is a resident living 25 meters from the edge of the unit.

Additional inputs used for the emission and dispersion modeling are summarized in Table 6-1.

6.1 Calculation of Risk and Hazard Quotient

To calculate risk from a specified chemical to a specified receptor, IWAIR uses the following steps:

1. Calculate emission rates from your inputs or use the emission rates that you entered; the emission rates are chemical-specific and, if calculated by IWAIR, depend on the waste concentrations that you entered.
2. Calculate dispersion factors from your inputs or use your entered dispersion factors; the dispersion factors are receptor-specific.
3. Calculate air concentrations from emission rates and dispersion factors; the air concentrations are chemical- and receptor-specific.

Table 6-1. Inputs Used for Example Calculation: Landfill

Parameter	Example Calculation Value
Method, Met. Station, WMU Parameters	
Meteorological Station	Huntington, WV
WMU Type	Landfill
Wastes Managed Parameters	
Chemicals	Hexachlorobenzene, Acrolein
Concentration (mg/kg)	Hexachlorobenzene: 10 Acrolein: 3
Waste Management Unit Parameters	
Temperature (°C)	13.12 (met station default)
Wind speed (m/s)	3.179 (met station default)
Total porosity (volume fraction)	0.5 (default)
Air porosity (volume fraction)	0.25 (default)
Biodegradation	Off (default)
WMU operating life (yr)	30
WMU area (m^2)	10,000
WMU depth (m)	2
Number of cells	25
Annual waste quantity (Mg/y)	500
Waste bulk density (g/cm^3)	1.2 (default)
Receptor Parameters	
Receptor type	Resident
Receptor distance (m)	25

4. Calculate risks or HQs from air concentrations and, for carcinogens, exposure factors.

This example calculation does not cover the calculation of emission rates and dispersion factors in Steps 1 and 2. Using the inputs shown in Table 6-1, IWAIR calculates an emission rate of 1.56E−8 g/m^2-s for hexachlorobenzene, an emission rate of 5.36E−9 g/m^2-s for acrolein, and a dispersion factor of 3.37 [μg/m^3]/[μg/m^2-s], which is not chemical-specific (but corresponds to a receptor at 25 m).

Starting with Step 3, IWAIR calculates air concentration, as follows:

$$C_{air,j} = (E_j \times 10^6) \times DF \qquad (6\text{-}1)$$

where

$C_{air,j}$ = air concentration of chemical *j* (μg/m^3)
E_j = volatile emission rate of chemical *j* (g/m^2-s)
10^6 = unit conversion (μg/g)
DF = dispersion factor ([μg/m^3]/[μg/m^2-s]).

Plugging the values for emission rates and dispersion factor shown above into Equation 6-1 gives the following air concentration values:

$$C_{air,hcb} = 1.56E{-}8 \times 10^6 \times 3.37$$
$$= 5.26E{-}2$$

$$C_{air,acrolein} = 5.36E{-}9 \times 10^6 \times 3.37$$
$$= 1.806E{-}2$$

In Step 4, for carcinogens, IWAIR uses the calculated air concentration, the exposure factors, and the CSF to calculate carcinogenic risk, as follows:

$$Risk_j = \frac{C_{air,j} \times 10^{-3} \times CSF_j \times EF}{AT \times 365} \times \sum_{i=1}^{5} \frac{IR_i \times ED_i}{BW_i} \qquad (6\text{-}2)$$

where

$Risk_j$ = individual risk for chemical *j* (unitless)

$C_{air,j}$ = air concentration for chemical *j* ($\mu g/m^3$) = 5.26E−2 for hexachlorobenzene, calculated above
10^{-3} = unit conversion (mg/μg)
CSF_j = cancer slope factor for chemical *j* (per mg/kg-d) = 1.6 for hexachlorobezene
i = index on age group (e.g., <1 yr, 1–5 yrs, 6–11 yrs, 12–19 yrs, Adult)
IR_i = inhalation rate for age group *i* (m^3/d) – varies by age group, see Table 6-2
ED_i = exposure duration for age group *i* (yr) – varies by age group, see Table 6-2
EF = exposure frequency (d/yr) = 350
365 = unit conversion (d/yr)
AT = averaging time (yr) = 70
BW_i = body weight for age group *i* (kg) – varies by age group, see Table 6-2.

Table 6-2. Parameter Values Used in Estimating Time-Weighted-Average Exposure

Age Range	Body Weight (kg)	Inhalation Rate (m^3/day)	Exposure Duration (yrs)	Exposure Frequency (d/yr)
Child < 1 year	9.1	4.5	1	350
Child 1–5 years	15.4	7.55	5	350
Child 6–11 years	30.8	11.75	6	350
Child 12–18 years	57.2	14.0	7	350
Adult	69.1	13.3	11	350

Plugging the air concentration value for hexachlorobenzene and the exposure factors shown above into Equation 6-2 gives the following carcinogenic risk value:

$$\text{Risk}_{hcb} = \frac{5.26\text{E}{-2} \times 10^{-3} \times 1.6 \times 350}{70 \times 365} \times \left(\frac{4.5 \times 1}{9.1} + \frac{7.55 \times 5}{15.4} + \frac{11.75 \times 6}{30.8} + \frac{14.0 \times 7}{57.2} + \frac{13.3 \times 11}{69.1} \right)$$

$$= 1.04\text{E}{-5}$$

In Step 4, for noncarcinogens, IWAIR uses the calculated air concentration and the RfC to calculate noncarcinogenic risk (HQ), as follows:

$$HQ_j = \frac{C_{air,j} \times 10^{-3}}{RfC_j} \qquad (6\text{-}3)$$

where

HQ_j = hazard quotient for chemical *j* (unitless)
$C_{air,j}$ = air concentration for chemical *j* ($\mu g/m^3$) = 1.806E−2 for acrolein, calculated above
10^{-3} = unit conversion (mg/µg)
RfC_j = reference concentration for chemical *j* (mg/m^3) = 2E−5 for acrolein.

Plugging the air concentration value for acrolein into Equation 6-3 above gives the following HQ, or noncarcinogenic risk value:

$$HQ_{acrolein} = \frac{1.806E-2 \times 10^{-3}}{2E-5}$$

$$= 9.03E-1$$

6.2 Calculation of Allowable Concentration

To calculate an allowable concentration, IWAIR uses the following steps:

1. Calculate unitized emission rates from your inputs or use your entered unitized emission rates; the emission rates are chemical-specific and correspond to a waste concentration of 1 mg/kg or mg/L; if calculated by IWAIR, unitized emission rates are also specific to waste type (i.e., aqueous- or organic-phase).

2. Calculate dispersion factors from your inputs or use your entered dispersion factors; the dispersion factors are receptor-specific.

3. Calculate target air concentrations from target risk or HQ, health benchmarks, and, for carcinogens, exposure factors; the air concentrations are chemical- and receptor-specific.

4. Calculate waste concentrations from air concentrations, dispersion factors, and unitized emission rates, for aqueous- and organic-phase wastes.

5. Choose an allowable concentration from the waste concentrations calculated for aqueous- and organic-phase wastes.

This example calculation does not cover the calculation of unitized emission rates and dispersion factors in Steps 1 and 2. Using the inputs shown in Table 6-1, IWAIR calculates the unitized emission rates for aqueous and organic phases for hexachlorobenzene and acrolein, shown in Table 6-3, and a dispersion factor of 3.37 [$\mu g/m^3$]/[$\mu g/m^2$-s], which is not chemical-specific. These will be used in Step 4.

Table 6-3. Unitized Emission Rates for Allowable Concentration Mode Example Calculation ([g/m^2-s]/[mg/kg])

Chemical	Aqueous-phase	Organic-phase
Hexachlorobenzene	1.56E−9	1.12E−13
Acrolein	1.79E−9	7.28E−10

Starting with Step 3, IWAIR calculates target air concentrations by solving Equations 6-2 and 6-3 above for air concentration. For carcinogens,

$$C_{air,j} = \frac{Risk_j \times AT \times 365}{10^{-3} \times CSF_j \times EF \times \sum_{i=1}^{5} \frac{IR_i \times ED_i}{BW_i}} \quad (6\text{-}4)$$

Plugging a target risk value of 1E−5 into Equation 6-4 gives the following air concentration:

$$C_{air,hcb} = \frac{1E\text{-}5 \times 70 \times 365}{10^{-3} \times 1.6 \times 350 \times \left(\frac{4.5 \times 1}{9.1} + \frac{7.55 \times 5}{15.4} + \frac{11.75 \times 6}{30.8} + \frac{14.0 \times 7}{57.2} + \frac{13.3 \times 11}{69.1} \right)}$$

$$= 5.03E\text{-}2$$

For noncarcinogens,

$$C_{air,j} = HQ_j \times RfC_j \times 10^3 \quad (6\text{-}5)$$

Plugging a target HQ of 1 into Equation 6-5 gives the following air concentration:

$$C_{air,j} = 1 \times 2E\text{-}5 \times 10^3$$

$$= 2E\text{-}2$$

In Step 4, IWAIR uses an equation comparable to Equation 6-1 to relate target air concentration to waste concentration. However, this equation must be adapted to reflect the use of a unitized emission rate associated with a waste concentration of 1 mg/kg. The emission rate, E_j, is replaced by $C_{waste} \times E_{j,unitized}$, where C_{waste} is waste concentration in mg/kg and $E_{j,unitized}$ is the unitized emission rate for chemical j in [g/m^2-s]/[mg/kg]. This new equation, which assumes that emissions are linear with waste concentration, is as follows:

$$C_{air} = (C_{waste} \times E_{unit} \times 10^6) \times DF \quad (6\text{-}6)$$

where

C_{air} = air concentration ($\mu g/m^3$)
C_{waste} = waste concentration (mg/kg)
E_{unit} = normalized volatile emission rate of constituent ($[g/m^2\text{-}s]/[mg/kg]$)
10^6 = unit conversion ($\mu g/g$)
DF = dispersion factor ($[\mu g/m^3]/[\mu g/m^2\text{-}s]$).

Equation 6-6 may be solved for waste concentration, as follows:

$$C_{waste} = \frac{C_{air}}{E_{unit} \times 10^6 \times DF} \quad (6\text{-}7)$$

IWAIR uses this equation with both an aqueous-phase emission rate and an organic-phase emission rate, to estimate an aqueous-phase waste concentration and an organic-phase waste concentration.

For hexachlorobenzene in an aqueous-phase waste, plugging the air concentration calculated above, the unitized emission rate for aqueous-phase waste shown in Table 6-3, and the dispersion factor shown earlier into Equation 6-7 gives the following waste concentration:

$$C_{waste} = \frac{5.03E{-}2}{1.56E{-}9 \times 10^6 \times 3.37}$$

$$= 9.57$$

For hexachlorobenzene in an organic-phase waste, plugging the air concentration calculated above, the unitized emission rate for organic-phase waste shown in Table 6-3, and the dispersion factor shown earlier into Equation 6-7 gives the following waste concentration:

$$C_{waste} = \frac{5.03E{-}2}{1.12E{-}13 \times 10^6 \times 3.37}$$

$$= 1.33E{+}5$$

In Step 5, IWAIR then examines these waste concentrations to ensure that they do not exceed physical limits (i.e., soil saturation concentration for aqueous-phase wastes and 1E+6 mg/kg for organic-phase wastes). If either waste concentration exceeds the applicable limit, it is

discarded.[1] If both values are possible, IWAIR selects the lower of the two as the allowable concentration.

The soil saturation concentration for hexachlorobenzene, given the inputs in Table 6-1, is 26 mg/kg. Because the aqueous-phase concentration for hexachlorobenzene calculated above (C_{waste} = 9.57) does not exceed 26 mg/kg, it is possible and is not discarded. Similarly, the organic-phase concentration does not exceed 1E+6 mg/kg, and is therefore possible and not discarded. Since both aqueous-phase and organic-phase concentrations are possible, IWAIR selects the lower of the two as the allowable concentration. In this case, the aqueous-phase waste value is lower for the target risk of 1E−5; consequently, the allowable concentration for hexachlorobenzene is 9.57 mg/kg, based on an aqueous-phase waste.

The calculations for Steps 4 and 5 are similar for acrolein. In an aqueous-phase waste, plugging the air concentration calculated above, the unitized emission rate for aqueous-phase waste shown in Table 6-3, and the dispersion factor shown earlier into Equation 6-7 gives the following waste concentration:

$$C_{waste} = \frac{2E-2}{1.79E-9 \times 10^6 \times 3.37}$$

$$= 3.32$$

For acrolein in an organic-phase waste, plugging the air concentration calculated above, the unitized emission rate for organic-phase waste shown in Table 6-3, and the dispersion factor shown earlier into Equation 6-7 gives the following waste concentration:

$$C_{waste} = \frac{2E-2}{7.28E-10 \times 10^6 \times 3.37}$$

$$= 8.15$$

The soil saturation concentration for acrolein, given the inputs in Table 6-1, is about 45,700 mg/kg. Because the calculated aqueous-phase concentration for acrolein is below this level, the value is possible and is not discarded.

Similarly, the organic-phase concentration does not exceed 1E+6 mg/kg and is therefore possible and not discarded. Since both aqueous-phase and organic-phase concentrations are possible, IWAIR selects the lower of the two as the allowable concentration. In this case, the aqueous-phase waste value is lower. Thus, for a target HQ of 1, the allowable concentration of acrolein is 3.32 mg/kg, based on an aqueous-phase waste.

[1] If they are both discarded, the soil saturation limit or 1E+6 is used, whichever results in the greatest risk.